MODIS SEMI-ANNUAL REPORT
December 15, 2002 – June 15 2003

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RSMAS/MPO

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NAS5-31362

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CONTENTS

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B. OVERVIEW OF RECENT PROGRESS

Introduction:

The Terra-MODIS instrument is capable of producing the highest-quality global ocean color measurements currently available, both by its 12-bit digitizer precision and 1km global spatial resolution. This capability depends upon the proper and stable calibration of the ocean color water-leaving radiance. To date, the calibration of the Terra-MODIS Ocean color bands has been fruitful but also extremely challenging. While the calibration strategy for the MODIS ocean color algorithms is based on the heritage CZCS and SeaWiFs sensors, the sensor design and stability characteristics unique to MODIS have necessitated new innovations in the ocean color calibration strategy that are both intellectually and computational intensive. Both the sensor characteristics and the stability of on-orbit total radiance calibration have been revisited and scrutinized in the last 6 months prior to the vicarious calibration of water-leaving radiance against *in situ* measurements in preparation for compete reprocessing of the Terra Mission

Current status of characterization and calibration lessons learned:

<u>Creating Climate quality data records at 4km:</u>
The MCST calibration team has developed a sound strategy for the on-orbit calibration of the Terra and Aqua-MODIS ocean color bands. However, due to engineering limitations, MCST estimates that the accuracy of their on-orbit Lt is limited to the order of 2-3%. The challenge to the Miami Ocean Color Team is that if all radiance components were absolutely known this would still translate into a 20-30% error in the blue band (MODIS bands 8, 9, 10) retrieved water leaving radiance (nLw). In reality, any incomplete sensor characterizations, temporal variability, instabilities, uncertainties, and/ or problems in the atmospheric correction combine to result in much larger errors. Therefore, further characterizations and vicarious calibrations with *in situ* measurements must be performed. To produce climate-quality oceans products at spatial resolutions of 4km, the vicarious calibration must produce Lt's with a precision of 0.3% at 443 nm (and progressively less precision as the wavelength increases), 10 times more accurate than is now possible on-orbit. This has been historically accomplished successfully for CZCS and SeaWiFS by iteratively adjusting the Lt's until the retrieved satellite nLw agrees with the *in situ* calibration values over many subsequent reprocessings of the missions. This technique also has the desirable effect of compensating for many of the uncertainties of the atmospheric corrections in the nLw values. The production of climate quality data records (CDRs) to date required 17 reprocessings of CZCS over the last 20 years, and 4 reprocessings of SeaWiFS during the past 6 years. While the MODIS TERRA sensor has been operational for nearly three years, limited reprocessing to produce a CDR has occurred only for the validated period of November 2000-September 2001. Recent independent analysis of the reprocessed global 4km chlorophyll data by Watson Gregg (private communication) shows excellent agreement with over 600 *in situ* measurements from the SEABASS/NODC databases (Figure 9). Beginning in mid summer of 2003, the MODIS TERRA oceans data will again be subject to reprocessing from the period of

November 2000-March of 2003, (expected to be completed during October 2003) thus extending the CDR of MODIS TERRA. Figure 10 shows histograms of the RMS variation by latitude band using the same *in situ* matchup data as was presented in Figure 2 for the 3 MODIS chlorophyll products and the SeaWiFS product. The variance for both sensors is quite good, (10% RMS) and indicates good agreement and linkage between the retrievals from both sensors for reprocessed data. The RMS of both sensors is well below the Level 1 Mission Requirement of ±35% for chlorophyll a. The fact that even this –first- limited reprocessing of MODIS ocean data has created a seamless linkage with SEAWIFS chlorophyll estimates within specification bodes well for the future in regard to creating a continuous CDR across multi-sensors.

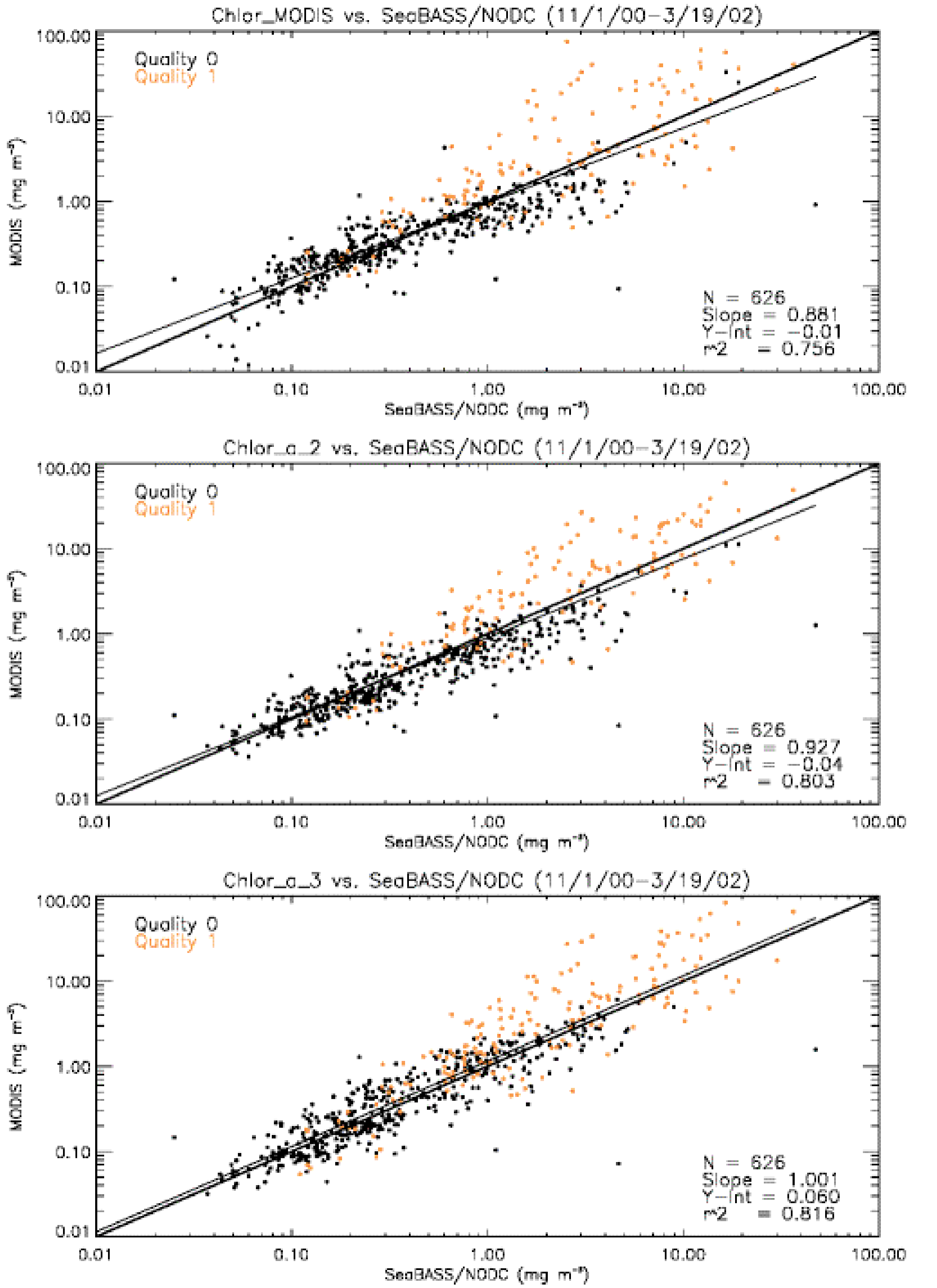
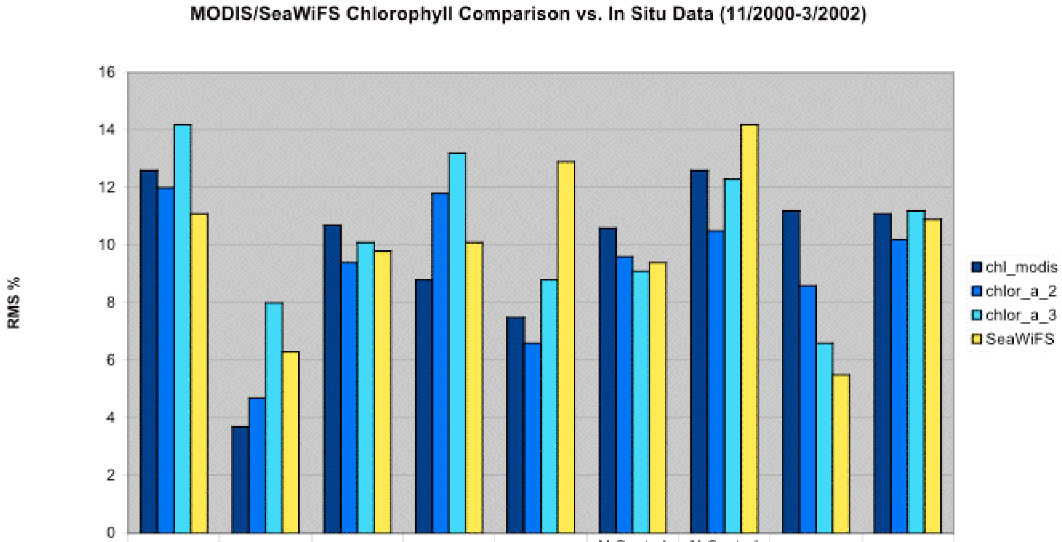


Figure 9. 4km global Chlorophyll in situ MODIS matchups comparisons for reprocessed validated period. Panel A: Chlor_MODIS Dennis Clark empirical algorithm B) Chlor_a2 seawifs analog algorithm, Panel C: Chlor_a3 Ken Carder semi-analytic algorithm. Data from Collection 4 validated period only.
Figure courtesy from Watson Gregg



	Antarctic (n=40)	S Pacific (n=3)	S Atlantic (n=25)	Eq Pacific (n=100)	Eq Atlantic (n=10)	N Central Pacific (n=175)	N Central Atlantic (n=175)	N Atlantic (n=60)	Global (n=600)
chl_modis	12.6	3.7	10.7	8.8	7.5	10.6	12.6	11.2	11.1
chlor_a_2	12	4.7	9.4	11.8	6.6	9.6	10.5	8.6	10.2
chlor_a_3	14.2	8	10.1	13.2	8.8	9.1	12.3	6.6	11.2
SeaWiFS	11.1	6.3	9.8	10.1	12.9	9.4	14.2	5.5	10.9

Figure 10: %RMS variance histograms for SeaWIFS and MODIS in situ matchup comparisons by Latitude band for MODIS reprocessed Validated period. From Watson Gregg

<u>Operational Forward-Stream and 1km swath products:</u>

The mechanisms for operational "forward-stream" processing of ocean color data have recently undergone significant upgrades which will help ensure their future accuracy and consistency. With the lessons learned by Miami and MCST and with improved sensor characterizations, a new strategy of bi-weekly calibration updates for Terra MODIS was put into the operational stream beginning in January 2003 and monthly updates for Aqua MODIS beginning with launch. This has dramatically improved the forward stream products and substantially minimizes the striping and mirror side artifacts in the operational products. This will prevent the quality of the forward stream data from diverging widely from that of reprocessed data, although history teaches us that reprocessing will always be required to produce a CDR. It is important to note that since the correction techniques developed at Miami are tailored to remove artifacts on a mean global basis, some low level detector striping may always be present in any particular scene in the 1km swath data, both for forward stream and reprocessed data. While visually this may be distracting to the eye due to its nonrandom nature in the cross-scan direction, in terms of scientific accuracy it is almost entirely inconsequential. This coherent noise is well below the precision of in situ measurements and has little impact on the scientific usefulness or interpretation of the data since it can be easily minimized by statistical compensation or by spatial and/or temporal averaging techniques prior to analysis.

Time instabilities:

The vicarious calibration and characterization approach taken by the Miami team has resulted in the quality of the Level 2 Ocean calibration and corrections being intimately tied to the state of the underlying Level 1B calibrations, especially as the L2 correction factors are very sensitive to the Lt values. Given a relatively stable or at least predictable ocean color instrument (such as SeaWiFS), the updating of the characterization and subsequent determination of the L2 correction factors would ideally occur on a relatively infrequent basis. However, the Terra-MODIS sensor top-of-the-atmosphere radiances have experienced numerous calibration shifts and drifts over the past 3 years of operation, occurring at an average of every 2-3 months. Time lags, on the order of 4-6 months, have been typical in the development and installation of the MSCT Level 1B LUT adjustments and the subsequent Miami characterization, correction, and calibration. These activities have been additionally plagued by the impossibility of predicting the future highly non-linear behavior of the MODIS sensor due to the non-monotonic behavior of the calibration changes. In fact, the eastern part of the scan behaves differently temporally than does the western side. The end result has been significant time- and location-dependent artifacts in ocean color products produced in the ***forward stream***. Any change in instrument behavior and/or any adjustments in the MCST L1B on-orbit calibration have required the Miami team to completely rework the vicarious characterization and calibration for oceans bands. Figure 10 shows a plot of the predicted L1b m1 calibration factors for each mirror side, based on fitted m1's present in the level 1b LUT at the time of forward processing, and the actual measured m1 values from the solar diffuser for the 412nm band. Two problems are immediately obvious: first, the instrument changes character quite frequently; and second, MCST's has had limited ability to predict calibration factors in to the future given the non-monotonic character of these shifts. Artifacts therefore were introduced into the forward stream processing, the severity of which was directly proportional to the departure of the actual measured m1 coefficients from the predicted values. The severity of the artifacts also was affected by the time lag inherent in the derivation of new calibrations/corrections and the installation of these into operations.

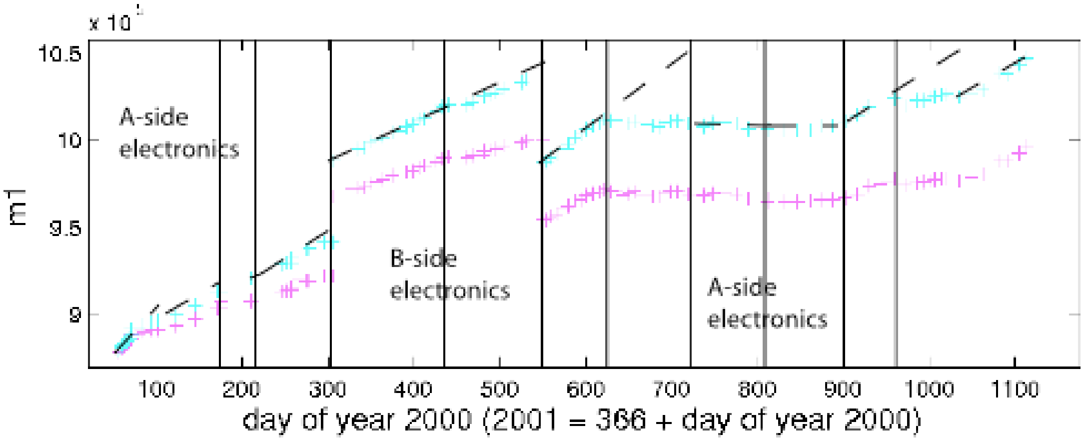


Figure 10 Band 8 412nm Time series measured solar diffuser m1's (blue mirror side 1, purple mirror side 2), and predicted m1's mirror side 1 at time of forward processing (dashed line).. Vertical black lines indicate complete vicarious re-characterization and calibrations epochs of oceans bands.

All ocean detectors for all bands shifted characteristics frequently, both in terms of relative mirror side differences, response versus scan angle, and relative band-to-band characteristics. To illustrate this multi-dimensional shifting, Figure 11 shows "waterfall" time series plots of the relative difference of the two mirror side behaviors as a function of cross scan position. These images are created by accumulating many granules over the Hawaii MOBY validation site, and calculating the mean cross-scan characteristics of each mirror side independently for each granule.

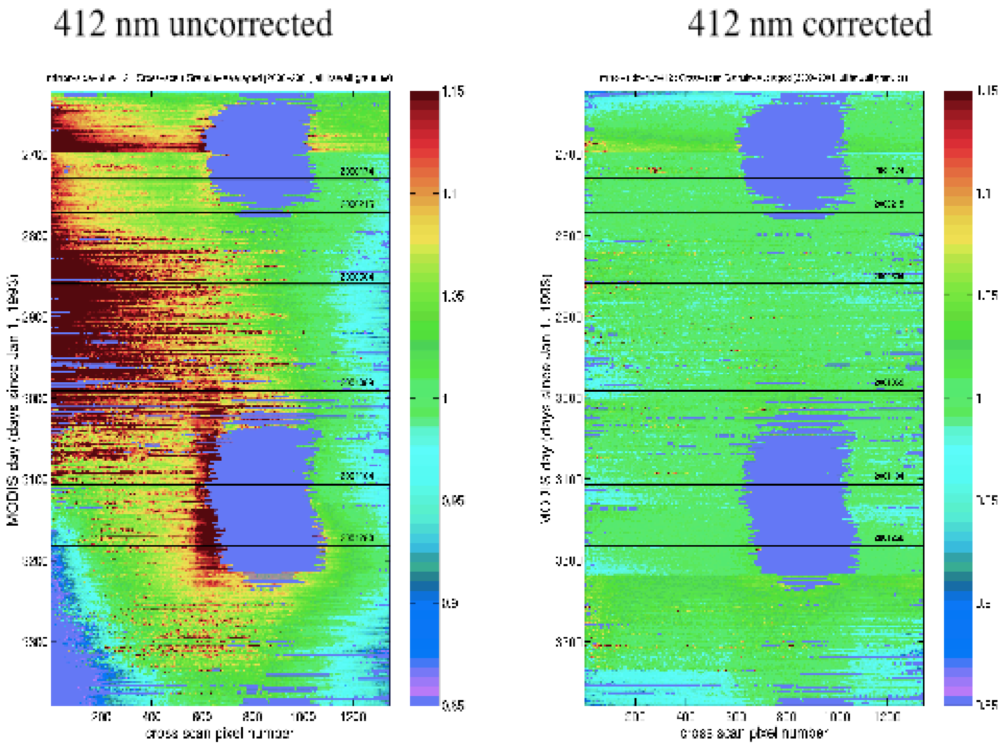


Figure 11-Waterfall plots of 412 nLw mirror side differences.
Y-axis days MODIS time coordinate, X-axis cross-scan pixel location.
Left panel no correction factors applied, Right panel: after corrections applied. Purple regions in the center for both panels represent seasonal sun-glint saturated pixels. Horizontal black lines denote oceans calibration epochs.

The left Panel in Figure 11 shows that both the mean relative mirror side difference and its cross scan behavior changes significantly (at least +/- 15%) in time . If the instrument is stable and well characterized it should appear as a relatively flat homogenous field. The ocean re-characterization epochs are shown superimposed as black horizontal lines. The right panel shows the relative mirror side behavior after the Miami mirror-side characterization and application of the derived correction factors for each epoch. Only after such a homogenous field is achieved can the absolute calibration be performed using the MOBY *in situ* data, since otherwise the large variance in mirror side and cross-scan behavior would swamp the absolute calibration effort.

The other corrections and mitigating factors that will be only touched upon here, for the sake of brevity, but also have very significant effect on the fidelity of the ocean color measurements. The spectrally- and temporally- varying absolute cross-scan behavior of the now-similar mirror sides have an error for nLw in the +/- 15% range, on a par with the mirror-side error. The effect of the temporally variant cross-scan error, again tied to uncertainties in the RVS of the mirrors, is apparent between data from adjacent orbits. A method similar to the mirror-side correction was applied to achieve spatial conformity, relative to a reference pixel (pixel #400 in cross-scan space). The balance among detectors within a band, with an nLw error of typically 3%, was achieved through statistical means but also has a temporal variation due largely to the changes in the magnitude of m1, and each detector actually has a different cross-scan behavior that varies in time along with the optics. Similar problems are associated with the near IR bands at 749 and 869 nm (bands 15 and 16). Lack of a suitable *in situ* reference analogous to the MOBY mooring at present precludes performing a correction equivalent to that achieved in the water leaving radiance bands (8-14). This will be addressed as part of the re-compete proposals.

Table 1 summarizes magnitude of the remaining variability in level 2 nLw as a result of the sensor characterization issues discussed, after the MCST L1b corrections are applied with no further correction at level 2, and after level 2 Miami corrections are included.

Issue	**effect on nLw images**	**Original variability after MCST corrections at L1B**	**Remaining variability after Miami corrections**	
		Variability	Variability	Quasi-random
Inter-detector	Occasional striping, cross-scan variation	+/- 3% at center of scan +/- 6% at edges of scan	<1% at center of scan +/- 3% at edges of scan	3% 412 nm ** 3% 551 nm **
Cross-scan	Mis-matches between adjacent orbits	30% @ 412 nm 30% @ 551 nm	<1%	3% 412 nm ** 2% 551 nm **
Mirror-side	Occasional banding	15% @ 412 nm 6% @ 551 nm	<1%	<1% 412 nm <1% 551 nm
Absolute calibration	Temporal variations	4% +/- 15% @ 412 nm	<1%	1 0% 412 nm 10% 551 nm

Table 1. Magnitudes of remaining nLw variability, both systematic biases and quasi-random variability in L2 products after MCST and the Miami corrections. Those quantities marked with asterisks (**) have a substantial portion of real geophysical variability included in the estimate.

Table 2 summarizes the magnitude of the correction factors applied during level 2 processing to dramatically reduce instrument artifacts.

Issue	**effect on nLw images**	**Lower bound of correction in % of Lt value**	**upper bound of correction in % of Lt value**
Inter-detector	thin stripes	+0.2%	+0.8%
Cross-scan	poor east-west gradients	-3.0%	+3.0%
Mirror-side	thick banding	-1.5%	+0.1%
Absolute calibration	overall value	-3.5%	+0.5%

Table 2. Types and magnitudes of visible corrections implemented in the Miami L2 corrections to the visible ocean bands. While there is spectral and temporal variation in these values, they are typical magnitudes of the problems addressed.

Absolute nLw calibrations against MOBY:

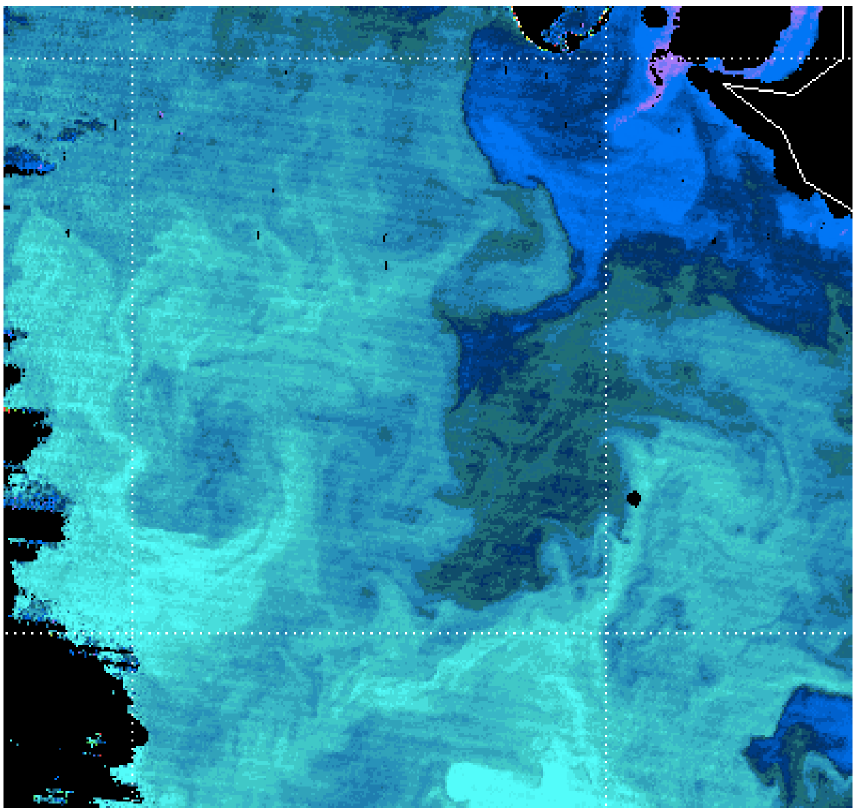
Due to the high frequency of these calibration shifts, one of the first issues that was overcome in performing the absolute calibration was the lack of sufficient numbers of high quality *in situ* MOBY versus MODIS overpass matchups within a given epoch. Given cloud cover, sun-glint, optimal viewing geometries, and the need for homogenous geophysical variability around the buoy, it generally takes a minimum of 6 months to 1 year to collect sufficient in situ data to enable any reasonable calibration analysis. Obviously, many of the epochs were much shorter than this 200-300 day time scale and current analysis suggests that the maximum period should be between 50-100 days.

To minimize the effects of clouds/glint on the retrievals and build as complete a time series as possible, a strategy was developed using a modal time series analysis of MODIS granules over Hawaii, whereby the mode of the declouded nLw field surrounding (radius of 300km) the MOBY site was calculated for each granule in the time series. These modes were then screened and filtered to *approximate* a continuous time series over the MOBY site. The main use of the modal time series for each band is to adjust the gain factors to promote temporal continuity across inter-epoch boundaries. Only once a temporally consistent time series was achieved were the highest quality MOBY/MODIS matchup data from the entire lifetime of the mission used to establish the final calibration. In 3 years, less than 20 good, cloud-free matchups are used in the absolute calibration procedure for Terra-MODIS, although MOBY collects data 3 times every day at the time of Terra, Aqua, and SeaWiFs overpasses. The number of valid matchup points for MODIS is approximately the same as collected for SeaWiFS over a 5-year period. These good matchups are used in the calibration process to remove any residual bias remaining in each band, as well as to evaluate (but not determine) the mirror-side and cross-scan correction procedures. Analysis to date indicates that MODIS is an incredibly sensitive instrument; the RMS of the corrected MODIS data remarkably approaches that of the *in situ* measurements themselves. The MODIS sensor in fact is so sensitive that significant geophysical variation has been detected in what previously had been considered an area of extremely low geophysical variability immediately surrounding the MOBY buoy itself. Thus, issues such as the watch circle of the buoy and exact geo-location of both the pixels and the buoy at the time of overpass and how this relates to local oceanic gradients have become important in selecting the calibration matchups and thus understanding the true RMS and uncertainty of the MODIS measurements. Improvements in the accuracy and uncertainty of the MOBY measurements are also an ongoing synergistic activity. Post deployment buoy calibration and in situ QA activities are fed back into the calibration strategy. NIST stray light calibration of the optical instruments on the buoy and revised MOBY nLw's were made available in the spring of 2002, the improved in situ measurements were also used in retrospective vicarious calibrations.

Controlling uncertainty in the forward stream by *not* predicting the future:

With the mirror degradation characteristics shifting frequently, it became clear in discussions between Miami and MCST during December 2002 that the use of predicted m1's in the forward stream was not prudent. In practice, the revised v4.0.9 LUT was out of date almost before it was even installed in the forward stream! The sensor's rapid variations in behavior resulted in the reappearance of stripes and artifacts in the forward stream as the predicted versus measured m1's diverged. In January 2003 MCST and Miami introduced a new strategy for the forward processing stream for both Terra and Aqua, where the Level 1B LUT calibration coefficients are updated at a frequency at least monthly, and possibly bi-weekly. These LUT updates will be based on the most recent measured solar diffuser m1's rather than predicted values. Commensurate updates will be required for the Ocean Level 2 calibration correction files, but perhaps at a lower frequency since the new strategy minimizes the effect of the temporal changes. Tests of this rapid response calibration strategy at Miami demonstrated that this minimize d(but not remove) artifacts and calibration drifts in the forward stream, and thus should provide a more reliable means of generating operationally useful products. MCST estimates that the uncertainty in the spectrally dependent solar diffuser measurements is approximately 0.3 to 0.6%, which will introduce additional noise (3-6% in nLw) in the system. The additional uncertainty in water-leaving radiances in the forward data will be on the order of 1.5-2 times the uncertainty seen in reprocessed data resulting from detailed retrospective sensor characterizations and calibrations. In effect, an efficient trade-off is being made between the stability of the forward stream operational ocean products and the high quality of the retrospective research products.

For comparison purposes, Figure 6 shows a Jan 31st granule processed with the predicted level 1b (v4.0.9) and Miami corrections that were in operations on Jan. 30. Striping and other artifacts are clearly present. Figure 7 shows an uncorrected image for Jan 31 2002 using the new measured m1's strategy (L1b 4.1.2.1). While some inter detector striping is present, the mirror side and cross-scan behavior is dramatically improved compared to that seen in Figure 6. Transects across the 10 detectors have an average error of ~5% compared to 15% in figure 4. Figure 8 shows the same Jan 31 images after the corresponding updated Miami corrections and calibrations have been applied, which has had the anticipated effect of improving the accuracy and quality of the image. While subtle striping is visually present the error across the 10 detectors has been reduced to <3%. As stated previously, the adoption of the new approach will assuredly introduce some additional uncertainty in the forward stream; should the instrument continue to change on time scales less than 1-2 months some low level striping may occasionally be present as a finite time lag is required to complete Miami's characterization and calibration analysis. However, large departures from this quality state in the forward stream are much less likely. Periodic reprocessing efforts will be required to produce the highest climate quality data sets that MODIS sensor is capable to producing.



Figures 6 – nLw 443nm Jan 31, 2003 processed in the forward stream using predicted m1's present in v4.0.9 level 1b and Oceans radiance corrections v13_16.

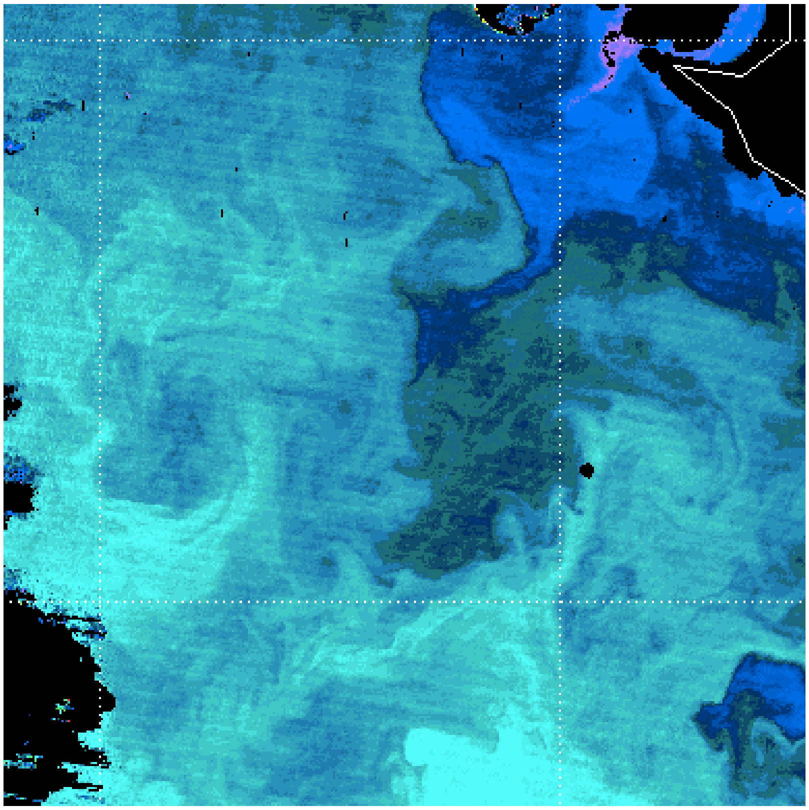


Figure 7- nLw 443nm Jan 31, 2003 processed with the real m1's v4.1.2.1 level 1b with no oceans radiance corrections.

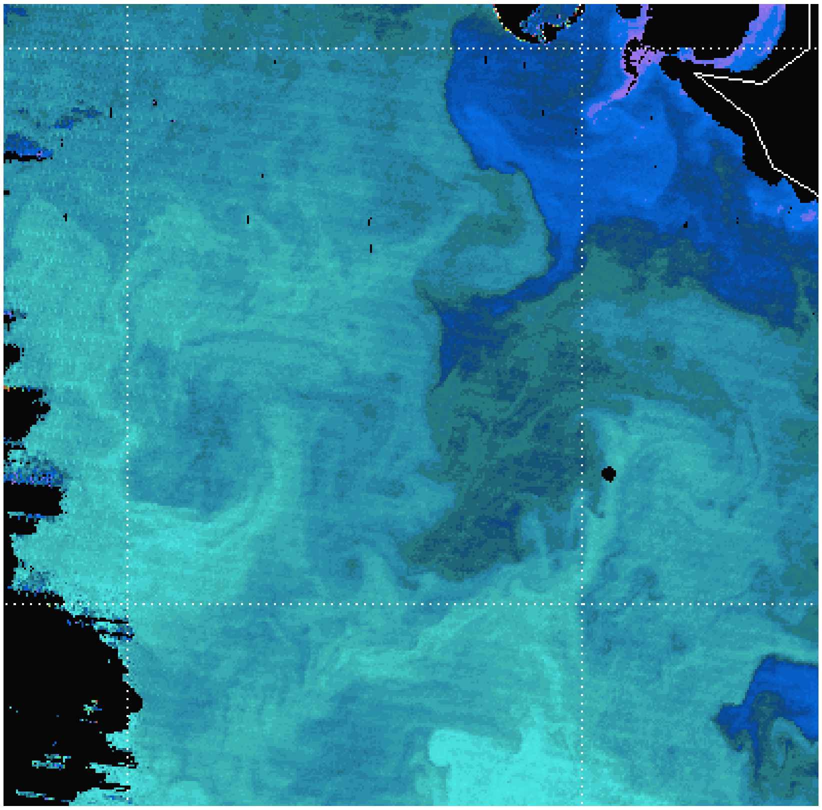


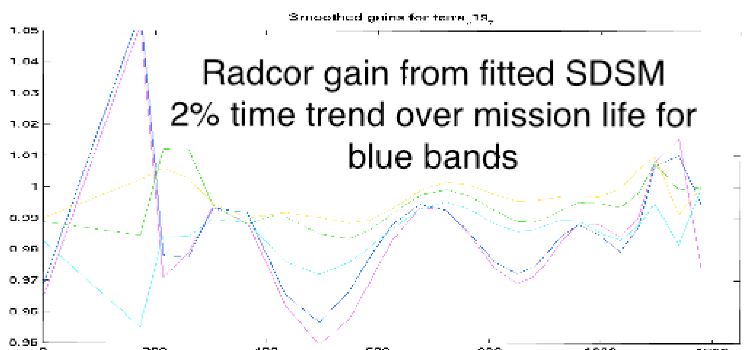
Figure 8- nLw 443nm Jan 31, 2003 processed with the real m1's v4.1.2.1 level 1b and the corresponding revised Ocean radiance corrections and calibrations. (V15_53)

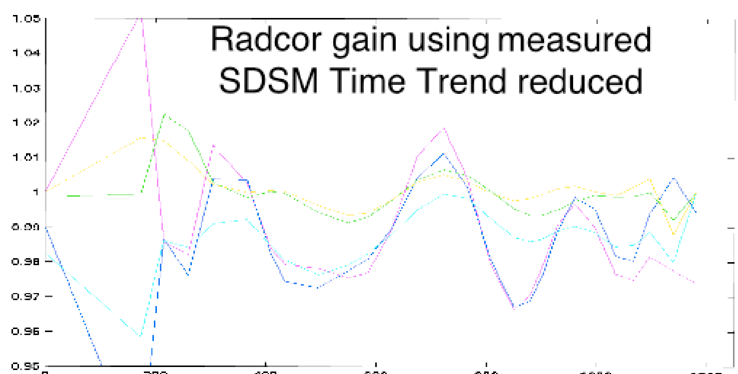
B.1 Processing and Algorithm Development Ocean color (March to June 2003)

Several major issues were addressed in the revised ocean color code V4.10.0 and focused on the temporal stability of MODIS ocean products over life of Terra mission to date, to enable reprocessing and create a climate quality data record. QA analysis of collection 4.0 global and regional 36 and 4km images by the MODIS Oceans Data Assessment team (MODAT) and the SeaWiFS/SIMBIOS project indicated that residual problems likely associated with polarization, sun glint and BRDF were still largely unresolved. Furthermore, orbit-to-orbit East –West trends were occasionally present at certain seasons and latitudinal bands and required revisions to the polarization correction tables. As stated earlier the Terra-MODIS sensor top-of-the-atmosphere radiances have experienced numerous calibration shifts and drifts over the past 3 years of operation, occurring at an average of every 2-3 months. Working with MCST the L1b calibration was revised several times during the last three months in an effort to reduce these calibration shifts.

In preparation of the revised code and calibration to be used in the next reprocessing several major questions were re-visited and investigated in an effort to minimize remaining artifacts. These included temporal stability in regard to the source of L2 ocean RADCOR gain oscillations and Epoch to Epoch transition continuity; Spatial stability both geographically, East-West, North-South , and residual mirror side and detector banding. In conjunction with MCST, Miami, and the SeaWiFS project a complete end-to-end and line by line review of the level 1b and oceans l2 code was under taken. Several minor coding errors were identified and corrected. Subsequent testing of the fixed code confirmed that these errors were not the primary source of calibration instabilities.

Review of the l1b calibration techniques and raw calibration data used by MCST to develop L1b LUTS identified differences between 'fitted' and 'measured' solar diffuser stability monitor (SDSM) corrected solar diffuser data. In late May MCST produced an experimental L1b LUT based on measured SDSM/SD m1 coefficients and a new L2 RADCOR was produced and continues to be refined based on the new L1b calibration. Using the measured SDSM removed a 2% life of the mission gain trend in the oceans RADCOR. However, the seasonal oscillations in the RADCOR gains are still present, the source of this oscillation continues to be investigated jointly by Miami and MCST. Current thoughts suggest that the solar diffuse screen and the fact that the earth is visible to the SD thru the screen may be playing a role.





In regard to the L2 oceans algorithm additional investigations relating to the atmospheric correction were explored. This included incorporation of a bi-directional reflectance algorithm and revisions to the sun glint Cox-Munk calculations to include a polarization term. A brief description of the code and calibration changes for reprocessing (Oceans V4.10.0) is summarized below. Additional details on changes associated with the atmospheric correction algorithms can also be found in the Jan2003-June 2003 semi-annual report of Voss and Gordon.

Description of Changes:

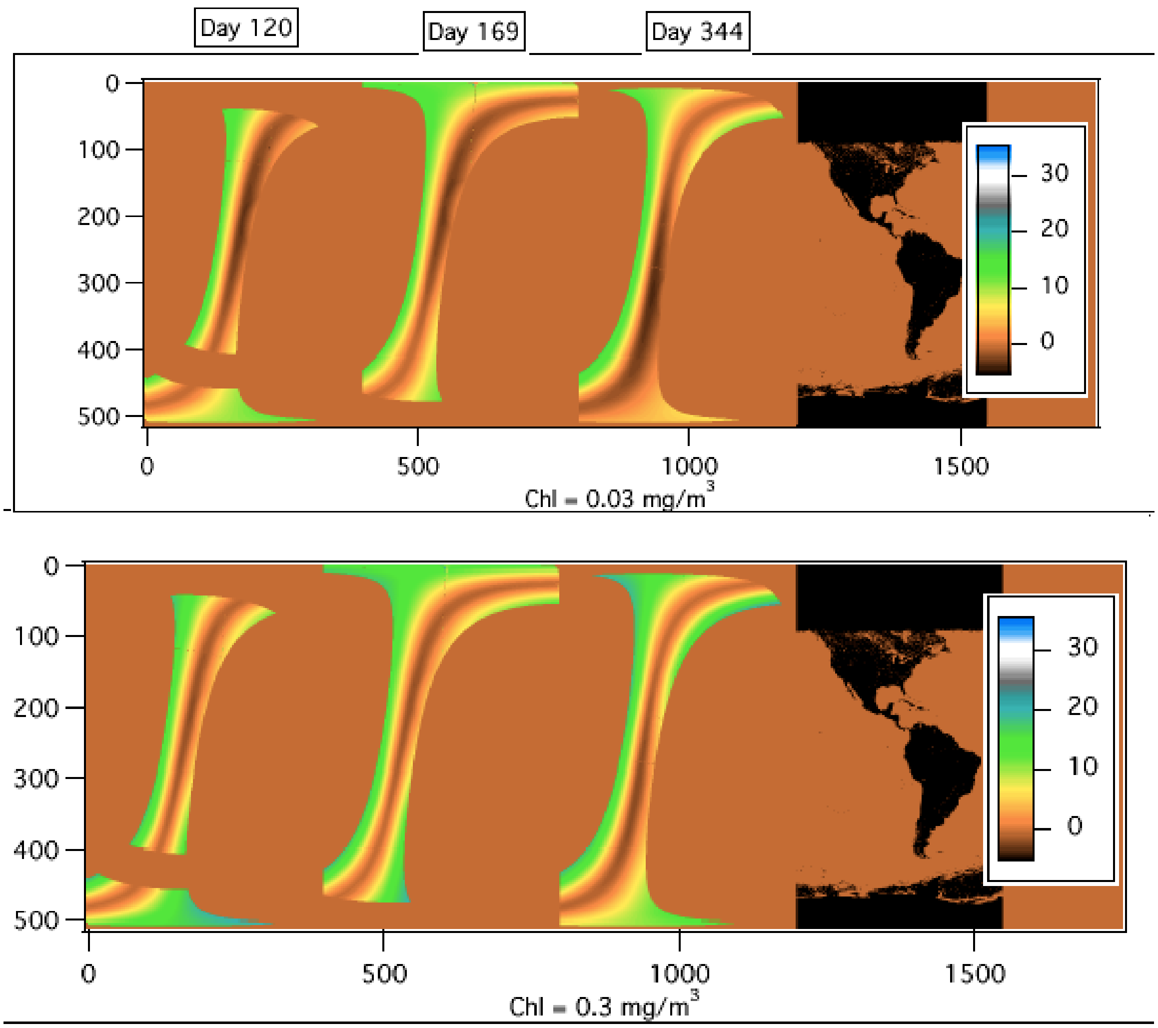
1. **Level 1 calibration and code change**: Level 1b V4.2.0_M PGE02 will be used during the oceans reprocessing. The V4.2.0_M l1b includes a special LUT developed by MCST for reprocessing of oceans bands. This L1b radiance calibration LUT is based on bi-weekly solar diffuser measured M1's and measured solar diffuser stability monitor (SDSM) rather than fitted/smoothed values. Extensive testing at Miami indicates that this LUT provides the best temporal stability to date. In addition, a small error was found in the PGE02 code, the solar variation equation used to correct the earth sun distance had an error in the sign of the second term. While the impact of this error on oceans bands was negligible, for consistency it was corrected.

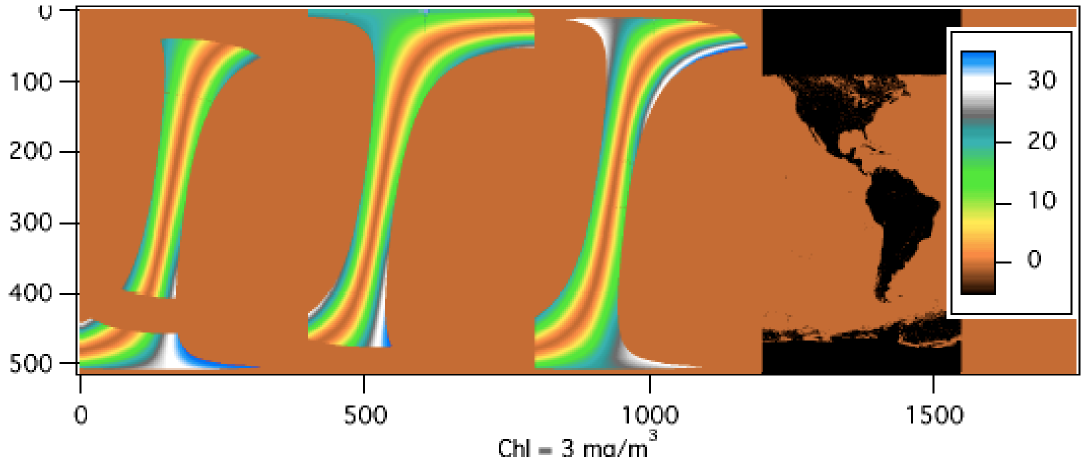
2. **Solar constants changed**: The Oceans code was modified to use as input the radiance scaling from l1b rather than reflectance scale. Conversions between radiance and reflectance space were modified to use the same per band per detector solar constants (Fo) used by MCST, that is Thuillier 1998 for the 0.4-.8 micron bands, and Neckels and Labs 1984 for 0.8-1.1 micron bands. Previously the oceans code used only Neckels and Labs for all bands. Theoretically if a consistent set of Fo's are applied internally to ocean code when converting between reflectance and radiance the fact that MCST used different Fo's should not have had an impact on the derived water leaving radiance values. However, to ensure that there could be no inconsistency between MCST and Miami's handling of the L1b radiances the oceans code was changed.

3. **Revised Polarization tables**: Polarization table re-analysis was conducted using the original test data and an updated correction strategy was produced and tested at Miami. The original polarization sensitivity correction assumed that Lt was polarized in the same directions as Lr, the new correction assumes that only the Rayleigh component is polarized ie. aerosol and water radiances are non-polarized.

4. **Bi-directional reflectance** (BRDF): A BRDF algorithm was incorporated into the oceans code. Using the viewing geometry from MODIS and nominal chlorophyll values (0.03,0.3.3.0 mg/m3) the Morel and Gentili 2003 algorithm was used to model the sensitivity of MODIS to BRDF as a function of season. It was found that the sensor was extremely sensitive to BRDF and could account for much of the MODIS cross-scan variations. On each of the three figures below are shown

the percent difference between nadir radiance (Lnadir) and the view geometry radiance (Lview) at 412nm as a function of day of the year (days 344 NH winter, 120 spring, and 169 summer) for three chlorophyll concentrations. In each case one representative swath is shown for each of the 3 days. Several important results of this sensitivity analysis stands out, since the orbit is not directly north south, the BRDF factors do not change in a symmetric manner from North (NH) and Southern Hemisphere (SH) during winter and summer and likely explains some of the cross scan SH summer artifacts seen in collection 4. Furthermore, BRDF is very dependent on chlorophyll, at high chlorophylls the factor is very large along the edge of the scan (+30%). Secondly, the BRDF was found to be spectrally variant (figures not shown). At the lowest chlorophyll concentration the ratio is bounded by about 0.97 to 1.02, but at the higher chlorophyll this value can range from 1 to 1.1 for 490nm./412nm and .95 to 1.15 for 560nm/412nm.





The conclusions of this sensitivity analysis are that the BRDF factor is spectrally dependent for MODIS, and the SH is not just a later (or earlier) NH, as had been assumed in the statistically derived cross-scan correction factors developed previously for collection 4, and finally that the BRDF factor for MODIS can at times be much larger than originally assumed. Given these findings it was decided to immediately include this BRDF algorithm into the oceans code rather than wait for a future release. The preliminary images processed in Miami showed dramatic improvements in the cross-scan direction, with no additional cross-scan corrections required. Furthermore, the BRDF algorithm's more proper handling of the cross-scan radiance enabled better statistical estimation of the mirror-side, and inter-detector correction factors. A limited time series subset processed at Miami suggests that transient mirror-side and inter-detector striping is much reduced relative to that seen in collection 4. This was an unexpected result of inclusion of the BRDF algorithm, it is assumed that the single set of empirically based cross-scan correction factors previously developed at the Hawaii validation site were clearly insufficient when applied globally and in different seasons and may have hindered the accurate statistical determination of the mirror-side and inter-detector correction factors.

5. **Sun glint with polarization and coding error**: A minor bug was found in the implementation of the Cox-Munk sun glint equation, a Pi/Mu_o term was missing. This error was corrected, however, the impact of this error on the previous science was determined to be minimal due to the fact that sun glint contamination is important only when Pi/Mu_o is close to unity. Before and after code fix tests at Miami confirmed little difference in the glitter correction pattern or amount after this error was corrected.

   Due to the MODIS sensors sensitivity to polarization, Howard Gordon modified the standard Cox-Munk glitter formulation to included polarization effects in the glitter calculation. Inclusion of glitter polarization results in some minor improvements but further refinements will be needed in the future, likely related to vector winds and the shape of the Cox-Munk function, investigations are on-going.

6. **Revised RACOR with inter-epoch smoothing**: The Oceans RADCOR LUT was completely revised as a result of the above listed changes and the new L1b calibration LUT. In addition, to reduce step functions at epoch transitions, a quadratic smoothing technique is used to interpolate the calibration coefficients across epoch boundaries.

Minor changes:

7. **QA tracking version history and file name version ID**: To more easily track the entire production history of a granule the upstream production history is chain ganged and written directly to the metadata in each HDF file along with the downstream oceans PGE production history. This will enable the user to see all PGE version numbers and LUT's used from L1-> L3 that was used to produce a given granule. To facilitate easy identification in the ordering system of forward stream provisional products from reprocessed climate quality products a version ID has been incorporated into the filename. The third digit of the granule ID version number will be used to convey this information to the user. For collection 4 products <*.040.*.hdf > will indicate granules produced in the forward stream, while <*.041.*.hdf > will indicate a reprocessed granule.

8. **Clark Chlorophyll products upper limit threshold changed**: The maximum allowable upper threshold for chlor_MODIS, CZCS_pigment, and Pig_total was changed from 100mg/m3 to 120mg/m3. The revised coefficients installed in the previous code enabled consistent retrievals at very high chlorophyll levels.

Sea surface temperature

MODIS SST cloud test: The day time sea surface temperature cloud flagging is based on the oceans visible band nLw 678 homogeneity test, thus the ocean color changes listed above were also incorporated into both PGE 9&10, the core SST and SST4 algorithms and coefficients remain unchanged from those of v4.5

B2. Matchup databases and Validation activities

Both the sea surface temperature and ocean color 1km matchup databases were extended in time to the current leading edge. The entire life of the mission matchup databases were reprocessed several times to explore, quantify, and validate code changes.

Direct Broadcast and Miracle Web site

<u>Direct broad cast</u>
The Miami level 2 direct broadcast web pages and 14 day rolling archive including data and images from both AQUA and Terra Sensors continues operational during this period.

B.4 Systems Support

Specifics of delivered code changes V4.10.0 (Revision control documentation)
modcol:
Correct calculation of thesat6.
Echo actual file name of oob file from pcf.
Copy Reflective and Emissive LUT Serial Number attributes from L1b.
Add LOCGRANIDV input to set LocalVersionID and the version number in LocalGranuleID.
Reverse detector order since tables are in Santa Barbara detector order.
Go back to not flipping the polarization data.
Update and output Production History metadata.
Algorithm and coeff updates for Clark products.
Use input file names from pcf in messages and metadata.
Add HDF5INC for the 5.2.8 toolkit.
Fix file names in open/close messages.
Fix open/close file messages.
Make room for more epochs in corrections file.
Add ability to read PGE18 output MODOCREY, hdf version of oisst.
Add ability to read hdf version of oi v2 data (MODOCREY from PGE18).
Add checks of bitQAflag from L1b for bad scan lines.
Fix nLw quality check of B_Lw_Counts_Lw in lwflags, not comflags.
Add new coccolith inputs to processing log. Fix checks using doavgch1 to skip processing of detector 1. Change upper limit for czcs_pigment and chlor_modis to 200 instead of 100.
Call new_coccolith_MODIS5.f instead of new_coccolith_MODIS4.f.
Add two command line inputs for new coccolith routine: BB_P_CCLTH and AM_P_CCLTH.
Fixed check for cloudy bit in test for chlor_a_2 quality 3.
Update date in copyright notices. Pass new inputs: bb_p_cclth and am_p_cclth to cclth_6_8_9.
Changed all the x7's to x8's in the write statements and deleted the 'x7' variable declaration since x7 isn't used.
Disable numerous debug print statements (with 'd').
Set 'Quality_Bits' attribute for the F* files so they can be binned.
Use radiance calibration (instead of reflectance calibration).
Derive F0* from radiance and reflectance calibration slopes (rad/ref*pi).
Return F0* values to calling program.
Status codes are positive.
Return time at middle of granule (used to correct f0star).
Build list of (blank separated) input product/ancillary files
L1b file has to be first in the list for v2_meta to read ProductionHistory.
Put 'convergence failed' error message in correct position.
Disable old f0var ASF (generates incorrect values).
Add f0var solar variation function (duplicates calculation in PGE02).
Add seqjul time conversion function (needed by new f0var function).

Retrieve F0* from L1B file.
Convert F0* to F0 (using time at middle of granule).
Compute f0corr for every scan line.
Change upper limits for CZCS_pigment and chlor_MODIS to 120, and pigment_c1_total to 240.
Print correct values in debug.
Enable NIR correction.
Restore Rayleigh scattering to NIR t_rho_w calculation.
Enable polarization correction.
Put dustratio in F2 slot 10 instead of seawifs chlor (oc2v2?).
Set DustRatio to 0.0 if it can't be calculated.
Initialize input LUN array before the first input file.
Pass L1b_LUN to v2_meta so it can read Production History.
Correct the equation for annual solar variation.
Initial versions of rgoth_subs.f foq_subs.f
Pass filename array to CreateOutputImage instead of a single filename to conform with the way CreateOutputImage now works.
Revise the glint correction to use glint reflectance instead of glint factor. Remove unused variables and ASFs.
Correct interpolation weight calculation, was off by 1.
Compute glint reflectance here instead of in wang3.f.
Apply F/Q correction to Lw and nLw.
Apply Rgoth correction to Lw and nLw.
Add debugging print statements.
Disable calculations on unused variable.
Correct mistake in glint aerosol atmos. attenuation.
Implement glint polarization correction.
Return Rayleigh reflectance to main routine.
Early exit from search loops when value is found.
Make sure in water angle is in proper range.
Disable unused PGS Toolkit include for time-date (TD) routines.
Correctly pass bitQAflags pointer to mod_get_l1b_record_v2.
Initialize variables used in read loops (just in case they don't get set).
Add explicit return type for routine.
Declare prototype for external routine OCEANS_SMF_SetDynamicMsg.
Add a few paren's to make code clearer.
Fix comment. Fix whitespace in filename messages.
Implement updated Rgoth tables.
Fix comment for input parameter.
Change radiance corrections to only do quadratic time correction OR In situ calibration adjustment. Also, quadratic time correction now uses epoch day instead of granule date.
Add adjustable glint sigma coefficients.
Fix SIGC,SIGU default values (was off by factor of 10).
Use original defaults instead of first guess adjustment.
Split glint correction into two ranges.

Select direct/diffuse glint correction (translation option).
Don't re-compute chlor. value for F/Q correction if glint is too large.

modsst:
Fix an error message. Write out the Reflective and Emissive LUT versions as attributes.
Add new input LOCGRANIDV to set LocalVersionID and the version number in LocalGranuleID.
Update and output Production History metadata.
Add option (reftype=4) to read hdf version of OI V2 made by PGE18.
Add checks of bitQAflag from L1b for bad scan lines.
Put Chan26 back in Q2 file instead of bsst which was there for debugging.
Fix a comment.
Set quality to 3 (bad) if sst (or sst4) value is not between -2 and 45.
Pass L1b_LUN to v2_meta so it can read Production History.
Pass filename array to CreateOutputImage instead of a single filename to conform with the way CreateOutputImage now works.
Get new paramter, EpochTime, from getcorrections even though modsst isn't using it yet.
Add wsigc,wsigu glint polarization command line arguments.
Add new input and output arguments to coloop call.
Removed unused local variable.

msbin:
Fix handling of year when granules are split.
Read LocalVersionID from input file for LocalVersionID and the version number in the LocalGranuleID.
Write flags to OC_F* outputs.
Update and output Production History metadata.
Add HDF5INC for the 5.2.8 toolkit.
Add error checking for invalid sstime from input file.
Add EOS to a message.
Pass input LUN and version to v2_meta so it can read Production History.

mtbin:
Fix comment in header.
Update and output Production History metadata.

mspc:
Update and output Production History metadata.

mmap:
Update and output Production History metadata.
Remove some debugs.

mcolshr8/colorsub8.c:

Print warning if humidity (actually p_water) is less than zero, but not if it's equal to zero.

modlib:
  invgeo:
Add HDF5INC for the 5.2.8 toolkit.
  modisio:
-O2 fixed with 7.3.1.2m (and newer)
L1B_Geo_Cld_Interface.c, modisio_v2.h:
    Read Reflective and Emissive LUTs version numbers to write out as attributes in the L2 files.
Fix reading of refl and emis LUTs from L1b - get length of attributes to null terminate the strings.

v2_meta.c, v2_meta.h:
Use version passed in from calling routine in LocalGranuleID instead of reading collection VersionID from input file.
Prepend PGE name, program name, and PGE version to ProductionHistory metadata.
Fix error message.
Pass in LUN and version of input file to read Production History.

  io:
errmsg.c:
Replace a global variable with a standard library call to be more portable.

  sphlib:
Add reflec_both.f routine.

atmcorshr:
readreyw_new:
  New routine to read hdf version of OI V2 made by PGE18.
hdf-wrd.c
  Add REFrdattr to read attributes from MODOCREY, the new PGE18 output hdf version of OI V2.
hdf-wrd.c:
  Remove unused variables.
colorin1.h
  Implement glint polarization calculation.
  Add two output parameters to each glint subroutine.
  Add new arguments to glitter routines.
glitter.f glittervec.f
  Implement glint polarization calculation.
  Add two output parameters to each glint subroutine.
  Change Sun glint wind scaling coefficients (now asymmetric values).

Externalize wind speed sigma coefficients.
getcorrections.rat
Return the start of the epoch which includes the granule being processed.

mcolshr8:
colorsub8.c:
Disable unused code and variables.
Add glint Q/U polarization variables to coloop and gliter routine calls.
Add new glint arguments to COLOOP.
get_climatology.c
Remove unused variable.

msstshr5:
avhrrsub5.rat
Add extra arguments used by gliter routine.
Set default values for inputs and ignore outputs.

binshr
Add HDF5INC for the 5.2.8 toolkit.
settbinmeta:
Read LocalVersionID from input file and use it to set LocalVersionID and the version number in the LocalGranuleID.
Pass program name to set Production History metadata.
Pass input LUN and version to v2_meta to read Production History.

modinc:
meta
Add comment about the granule id version from pcf instead of constants.
ocean_lun.f ocean_lun.h ocean_lun.rat
Add REY_WK_HDF_LUN, 900032, for PGE18 output of hdf version of OI V2.
Add F over Q data file.
Add LUN for Rgoth data file.
commoninout.rat commoninout.h
Correct LW flag bit 16 description.
Use correct descriptive text for DR2 flag bits 7 and 8.

mcloud:
Update and output Production History metadata.
Pass correct input file lun to settbinmeta.

mfill:
Update and output Production History metadata.

readpol-mod:
Initial warnings.
Add ability to switch side associated with calibration set.

readcal-mod:
Make room for more epochs in corrections file.

mremapn:
Add option to use calibration from input band. Use 255 instead of zero for default value for QUAL data.

reformat-ndt:
Add conversion scripts.

readdet-mod
Don't expect some header records.
Fix problem with second/subsequent band calculation.
Fix aqua/terra rsr scaling issue.

most of the seawifs and modis programs in dsp:
Add some linux ifdef's.

lib/io/dsplib.c:
include <time.h> instead of <sys/time.h>.

lib/io/errmsg.c:
Shut the linux loader up.

lib/wrktlk/wrkspc.h:
include <time.h> instead of <sys/time.h>

seawifsnav:
Change "type" to "print".

pathmap:
Bound output value based on PIXSIZ value.
Calculate bin row,column if VERBOSE=1.

pathnlc:
Remove ch4m5 from allb=4 option.

pathbin:
Remove ch4m5 from allb=4 option.
Add linux ifdef's.

io/dsplib.c:
Initialize COMDAT variable IFLG to QUTTY for standalone environment.

Add other comments.

ingest/lib:
Get rid of compiler warning.

scrpack:
Fix several portability problems.
Clean up code.
Fix variable initialization for linux.

scrpasmlt:
Initial version.
Must pass uppercase to TYP2ID.

tirpack:
Clean up code. Portability fixes.
Fix variable initialization for linux.

SCF upgrades:
A 20TB Apple raid disk array for on-line storage was purchased and installed at the RSMAS SCF. This additional disk storage facilitates processing and analysis of extended global times series subsets for validation and calibration activities.

B.5 Team Interactions

Participated in weekly teleconferences with MCST, PIP , and Oceans science team. Participated in the MODIS Oceans DATA workshop Feb3-4 University of New Hampshire. Joint meetings were held in DC in June 23rd between Miami SCF personnel and the SeaWiFS project office, and MCST to review code, calibration and explore new approaches. Participated in Aqua science team meeting,Washington D.C. May 30 2003. Three joint teleconferences, March, April, and May, were held with HQ personnel to discuss Terra current status and reprocessing plans.

C. Future Activities

C.1 Processing Development

Once the TERRA oceans reprocessing is underway we will be focusing on updating the calibration for AQUA in preparation for AQUA mission reprocessing, tentatively scheduled to begin Late 2003 early 2004. We will also continue to improve data quality tests to better identify suspect or invalid SST retrievals and continue work with microwave products to first identify and subsequently correct for the presence of aerosols in both the SST and Ocean color products.

C.2 Matchup Database

Continued work with D. Clark to collect MOBY and MOCE visible in situ data and examine MODIS cookie matchups from the standard and variable SeaWiFS validation sites. In regard to SST, we will continue to routinely extract 5x5 boxes of MODIS pixels for MAERI and buoy matchups for SST. Validation also continues by comparing retrievals from other sensors, eg. SeaWifs, AVHRR, AMSIR, ASTER.

C.3 Direct Broadcast

We plan to continue our direct broadcast web pages for AQUA and TERRA This include composites images for the U.S. East coast made available in GIF images, and binary format in addition to the standard EOS HDF of the 2.5min level 2 granules. Depending on user demand we may explore adding additional products to the current suite of available composites.

C.4 Systems Support

We plan to continue upgrading the RSMAS SCF with additional computational resources to support the demands of both AQUA and TERRA. These additional CPU's are needed to support the calibration, testing, algorithm development, and quality assurance activities associated with the two data streams.

C.5 Team Interactions

Continue participate in weekly teleconferences with MCST, PIP and Oceans and intermittent teleconferences and meetings with MODIS QAWG and interactions with MODIS Ocean PI's to coordinate algorithm and quality level and flag definition updates. We will continue interactions with the SeaWiFs product office in regard to activities relating to merged SeaWiFS MODIS products, and Ocean color validation activities. Work is planned with EOS and international teams to improve SST validation, exchange MAERI matchup observations and Terra/Aqua SST and SST4 global fields. Interact with GODAE Global High Resolution SST working group to better define estimation of diurnal thermocline leading to a proper merger of Aqua and Terra day and night SST fields.